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Offices of the Secretary
Federal Communications Commission
Washington, D.C. 20554

Dear Sir:

Enclosed find one original and nine copies of my Reply Comments to the NOI released August 12, 1993 regarding the definition and measurement of aural modulation limits, MM Docket No. 93-225.

Respectfully submitted,

Robert Orban
Chief Engineer
Orban, a Division of AKG Acoustics, Inc.

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93-225

Comments on MM Docket No. 930225: Means of Measuring Modulation in Broadcast

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Introduction

The Commission has requested comments on the issue of measuring overmodulation in the AM and FM broadcast services. This writer has twenty years experience designing audio processors designed to prevent the overload of transmission systems, and also designed the test procedure for the National Radio Systems Committee FM Subgroup's Working Group on FM Composite Spectrum Studies. I would like to present my comments on this issue.

I will concentrate my comments on FM, because this is where virtually all of the controversy lies. AM modulation is constrained by the need to meet the stringent requirements of the NRSC-2 RF mask, which can be easily violated by splatter due to carrier pinch-off. If modulation is adjusted by observing a current AM monitor of conventional design, splatter appears to be constrained to acceptable levels. Indeed, the NRSC-2 mask was based on measurements of a number of real-world transmitters fed with audio processed to the NRSC-1 standard and monitored with such conventional monitors.[1]

FM Monitoring

The present system of FM modulation measurement, although somewhat ambiguous with regard to the definition of "peaks of frequent reoccurrence," has nevertheless been effective in preventing objectionable interference between stations. A further advantage of the current system is that appropriate measuring instruments are low-cost, so any station can afford to have one or more in full-time operation, quickly detecting any equipment or operator faults causing incorrect modulation levels. Because of these undeniable virtues, the present system should not be abandoned without the most careful consideration.

Any method of measuring modulation should have as its goals

1. prevention of harmful interference,

2. prevention of receiver malfunction, and

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[1] For safety, many facilities double-check modulation with an oscilloscope to observe the RF carrier directly, checking it for any visual indication of carrier pinch-off. They may also configure the scope to indicate the "trapezoidal pattern," which shows essentially the same thing.

3. highest possible audio quality consistent with goals (1) and (2) above.

These goals should be achieved in the context of Rules that are clear, unambiguous, and evenhandedly applied.

Should Short-Term Overshoots Be Permitted?

Some have proposed the idea that audio quality could be improved if high-deviation, short-duration modulation overshoots were permitted by the Commission's Rules. This writer believes that this idea is flawed by the realities of FM receiver design. Experience, particularly in the communications industry, has shown that the audible effect of high instantaneous over-deviation is considerably more offensive at the receiver's output than is the audible effect of simply clipping off such overshoots. This is because instantaneous over-deviation that falls off the slope of the IF filter in the receiver starves the FM detector, which momentarily falls out of limiting and, depending on its design, produces a noise burst or other misbehavior for the duration of the over-deviation. Such misbehavior is more disturbing to the ear than is the effect of squaring-off the audio at the 100% deviation level prior to its application to the FM modulator. The most insidious problem with this sort of overmodulation is that its audible effect is highly dependent on the design of the receiver's detector and IF strip. The broadcaster, monitoring a program on a high-quality, relatively wideband receiver, might be totally unaware of the unpleasant noises that radios with narrowband IFs and/or significant design compromises were making while reproducing the same transmission.

In general, any over-deviation that forces the FM detector to misbehave is undesirable, and usually has worse audible consequences than conventional audio processing designed to limit instantaneous peak FM deviation to ±75kHz. All receivers are designed with the assumption that the deviation is so limited. Particularly in automobile radios, IF bandwidths are purposely kept as narrow as possible consistent with acceptable distortion assuming ±75kHz peak deviation, because good selectivity is a very important design goal in these radios. Auto radio manufacturers have stated this time and again in NRSC meetings.

It is undoubtedly true that there is a time threshold below which over-deviation can be permitted without serious audible consequence, either to the receiver or to adjacent channels. However, this writer's experience in designing clipping systems for audio processors strongly suggests that any peak with enough power to cause an audible quality improvement by its passage through the transmission/reception system also has enough power to cause audible mischief of the type discussed above. This writer submits that the time threshold below which no damage occurs is so short that such peaks have insignificant power and audibility, and could just as well be clipped off prior to modulation. This clipping would *guarantee* that no interference or unexpected, receiver-dependent artifacts would occur.

All modern audio processors of reputable manufacture have the ability to control their instantaneous peak output levels very tightly while simultaneously controlling their output spectrum well enough to prevent audible nonlinear crosstalk between the main and stereophonic subchannels (or vice-versa), and to prevent objectionable crosstalk into SCA subcarriers. Research has shown[2] that inconsistent peak deviation is almost always caused not by audio processors, but by inaccuracies in the *low frequency* response of composite STLs and FM exciters. Further *apparent* over-deviation can occur when similar problems exist in the peak flasher circuitry of modulation monitors, causing the monitor's peak flasher to be triggered even though no over-deviation is actually occurring.

Definition of Overmodulation

The above discussion leads inexorably to the conclusion that the definition of overmodulation should instantaneous peak deviation exceeding ±75kHz for any amount of time — a "brick wall," as it were. Because the RF can be observed at the transmitter's sample point, the monitor's FM detector can be made accurate enough to introduce no detectable error into the measurement.

From decades of practical experience, the current practice in "conventional" monitors (in which peak flashers typically respond in about 250µs) seems satisfactory. Indeed, measurements made under the auspices of the NTSC's Working Group on FM Composite Spectrum Studies (discussed further below) imply that, for conventional audio processing designed to provide such "brick wall" control, changing the flasher response time between zero and one millisecond scarcely changes the flasher's modulation indication. When the modulation is readjusted to compensate for any small changes in the peak flasher indication, the RF protection ratio changes by less than 0.5dB. This result indicates that virtually no loudness advantage can be obtained by slowing the response to one millisecond, and there seems to be little reason to do it.

As stated above, poor peak modulation control not representing deliberate, egregious overmodulation is almost always caused by low-frequency bounce and tilt in composite STLs and FM exciters. These overmodulation occurrences, because they are caused by the carrier's bouncing about at an infrasonic rate, are usually much longer than the one millisecond interval informally used as the maximum time window over which peaks can be ignored. This writer believes that overmodulation occurrences caused by such infrasonic bounce have a long duration, significant power, and cannot be ignored.

In almost all cases, such overmodulation occurrences can be eliminated by relatively simple modifications of the STLs and exciters in question. A properly operating transmission system, driven by any competent modern audio processor, will exhibit no significant overshoot *at all.* There is no question of ten, twenty, or a hundred peaks per minute; the instantaneous peak limit in a properly operating, reasonably state-of-the art system is absolute (within perhaps ±0.2dB) and readily achievable.[3]

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[2] Greg Ogonowski, "A New Approach To FM Composite Baseband Overshoot Control," *Proc. 1990 NAB Engineering Conference* Atlanta, GA, April 1990.

[3] The anecdote contained in footnote (11) of the NOI refers to a monitor for BTSC television stereo. Because of the proximity of the stereo pilot tone at 15.734kHz to the edge of the audio passband (at 15kHz), it is impractical to apply overshoot suppression to the filters required to protect the pilot. (Such overshoot suppression is routine in audio processors for the FM broadcast service.) All BTSC stereo systems known to this writer have considerable short-term overshoot

The only argument for permitting a hold-off time up to one millisecond for a peak flasher is that sometimes monitoring conditions are not ideal. A small amount of multipath in off-air monitoring can cause false, brief overshoots to emerge from the monitor's detector. However, the canny operator will never rely on the modulation indication of a monitor driven from an antenna at the studio; he or she will always rely on a monitor driven by the sample point in the transmitter.

Alternate Means of Measuring Modulation

Of particular consequence is the fact that *all consumer receivers have been designed based on this conventional modulation practice.* Some have proposed that modulation should instead be controlled such that the station occupies a certain specified bandwidth[4]. However, to this writer's knowledge, occupied bandwidth has not been shown to predict interference or receiver misbehavior any better than does peak deviation. In essence, the CCIR's occupied bandwidth measurement measures the long-term average power spectrum of the modulation and defines the occupied bandwidth as the bandwidth containing a given percentage of this power. This measurement ignores the peak-to-average ratio of the modulation, not to mention any psychoacoustic factors in the perceived sound of the interferer. It cannot indicate the annoyance quality of interference any more effectively than a signal's long-term, average power can indicate perceived loudness.

It is well established that the measurement that is fundamentally relevant to interference generation is not occupied bandwidth, but the "undesired-to-desired RF protection ratio." This is a well-accepted, internationally-recognized method of assessing interference[5]. Rau, Klein, and Keans's filing with the FCC regarding the effect of increasing permitted deviation when subcarriers are present[6] contains a good explanation of this method.

This method requires setting a criterion for the minimum acceptable signal-to-noise ratio of the demodulated audio (50dB has been proposed for FM stereo). The receiver is tuned to an unmodulated carrier. This carrier is then subject to interference from a modulated carrier on an adjacent channel. The RF level of the interfering carrier is adjusted to achieve the specified minimum audio signal-to-noise ratio at the receiver output. The ratio of the RF levels of the undesired and desired carriers is then measured. This ratio is termed the "undesired-to-desired RF protection ratio."

A given measurement of undesired-to-desired RF protection ratio is valid *only* for the particular receiver used in the test. It might also change with carrier frequency and with

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due to these filters and to the characteristics of the dbx noise reduction encoder used in the stereo subchannel. The spectrum allocation in the TV aural service is very different from the spectrum allocation in the FM broadcast band; there is no evidence that such short-term aural overshoots interfere with the visual signal. They certainly cannot interfere with the next channel's audio, because it is a minimum of 6MHz away!

[4] This can be measured according to CCIR Report 275-4.

[5] CCIR Recommendation 641

[6] M. C. Rau, H. J. Klein, & J. Kean, "The Effects of Increased Deviation of Adjacent FM Channel Protection," reprinted in "Draft and Unconfirmed Minutes of the National Radio Systems Committee — FM Subgroup; Working Group on FM Composite Spectrum Studies," November 15, 1989, National Association of Broadcasters, Washington, D.C.

variations in the absolute carrier levels used, depending on how well the receiver's RF and IF circuitry is designed. However, such differences will generally be small by comparison to variations caused by different receivers with different IF bandwidths or stereo decoder designs. (There is a major difference between the first-adjacent interference rejection of conventional "square-wave switching" decoders and "Walsh-function" decoders, for example.)

Rigor would demand that any RF protection ratio studies must be designed with a knowledge of the mean and standard deviation of the IF bandwidth of currently-manufactured mass-market FM radios. In the NRSC studies, the tests were repeated with three radios. Receiver designer and consultant Jon GrosJean stated to the NRSC that most mass-market radios use ceramic filters of identical design, and the main difference between the radios is whether they use one, two, or three of these filters in cascade in their IF strips. Thus, the NRSC measurements used as the three test radios a one-filter, a two-filter, and a three-filter radio.

Rau, Klein, and Kean[7] made an important advance in increasing the "real-world" applicability of the CCIR protection ratio test by modifying the spectrum of the audio modulation of the interfering carrier to make it correspond more closely than CCIR Noise to the "real-world" modulation practices of North American broadcasters who are using "competitive audio processing." To do this, they measured the long-term average spectral density of the emissions of several "highly-processed" stations, and then created a "Synthetic Program Noise" test signal that approximated this real-world spectrum.

However, Synthetic Program Noise fails to model at least two aspects of real-world program material: (1) its stereophonic content, and (2) its energy envelope, representing the dynamics of the program material. One candidate for an improved modulation source for the interferer is the "stereophonic pulsed USASI noise" developed by the NRSC in its work on AM broadcasting[8]. However, the NRSC has not studied whether the perceived loudness[9] of stereophonic pulsed USASI noise is similar to the loudness of typical "aggressively processed" speech and music. It is therefore unknown if pulsed USASI noise will cause interference that is psychoacoustically similar to the interference caused by real program material. For this reason, selected musical excerpts were used in addition to pulsed USASI noise as the audio modulation of the interferer.

Unfortunately, problems in the validation of the test bed rendered the results of the NRSC measurements unreliable and the study was not published. This experience indicates how difficult it is to do a study of this sort that is rigorous and whose results are considered scientifically valid by all involved parties. It is a warning to anyone proposing to change the modulation rules that such an endeavor is extraordinarily risky, with a high probability of failing to detect problems that might occur with certain program material, audio

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[7] op. cit.

[8] This is specified and a suitable generator is described in the NRSC-1 standard.

[9] Loudness is entirely subjective and perceptual. No commonly-used meter (VU or PPM) provides readings that correlate well to loudness as assessed by a panel of human listeners. Jones & Torick have developed a meter whose indications agree well with perceptual loudness. [See B.L. Jones and E. Torick, "A New Loudness Meter for Use in Broadcasting," *J. SMPTE,* 1981 September, p. 772.]

processing, and receivers in various combinations. The NRSC study was *only* about interference; it did not try to assess whether the proposed revised modulation practices would be compatible with almost all consumer receivers (as would certainly be required). Any proposal regarding a new way of measuring modulation must be validated with a large number of radios of different design, both for interference and for radio misbehavior on peak deviations exceeding ±75kHz.

This writer, therefore, believes that it is impractical to radically change the modulation rules. Decades of experience have shown that the current system prevents interference and ensures that radios operate according to their design parameters. The fact that some individuals believe that certain stations over-process their audio should not concern the Commission. People who consider a station to be over-processed can either listen to one of its competitors, or, lacking any station that meets their standards, turn off the radio. If enough people are offended and do this, the ratings services will quickly punish the station in question for its audio transgressions. There is a marketplace mechanism in place to determine quality standards; the current modulation rules (with a few loopholes closed) are quite sufficient to serve the Commission's mission of ensuring interoperability and preventing harmful interference.

At best, current data loosely implies that radically-changed modulation rules might permit a very modest 2dB or so increase in the loudness of lightly-processed program material. It is unclear that even this much would be possible after a rigorous, exhaustive search for potential problems. Any new measurement technique that supports this increase will certainly be more difficult and ambiguous than the current industry standard for modulation monitoring. This writer believes that there is a very small potential benefit to be achieved in exchange for a very large disruption, obsoleting current monitoring equipment and almost certainly causing serious confusion in the field, particularly with operators becomingly progressively less technically-oriented. Is any such change worth the price? This writer says no.